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Abstract

NUCLEAR CONSIDERATIONS IN THE DESIGN OF LARGE FAST POWER REACTORS

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The large, 1000 megawatt (electric), plutonium-fueled, fast power reactors under study today exhibit major differences in their nuclear characteristics from the U-235-fueled reactors of modest size currently in operation. Smaller reactors with medium enrichment fuel possess a harder neutron spectrum, a higher potential breeding ratio, and a considerable flexibility as to acceptable structural materials. Both the Fermi and EBR-II reactors employ an unrestrained, one-piece, metallic fuel element, which should expand axially during a power excursion, losing considerable reactivity and helping to terminate the accident. Both reactors have very small Doppler effects and substantially negative sodium void reactivity coefficients.

With the shift in attention to large core sizes and to ceramic or restrained metallic fuel elements, there has been a considerable reduction in the magnitude and reliability of the fuel expansion reactivity coefficient. Fortunately, the likelihood of a large, negative Doppler coefficient, has arisen. However, the prospect of large positive sodium void reactivity effects, overall or locally, has also entered.

In optimizing the nuclear design of large fast power reactors, one faces major conflicts among the requirements introduced by economics, by breeding, and by safety. The thicker blankets associated with higher breeding ratios can penalize economics. Cladding materials like niobium or molybdenum are harmful to breeding and to reactivity coefficients. Deliberate spectrum softening enhances the Doppler effect, but damages breeding.

The first section of this paper deals with the neutron physics performance of a wide range of large fast power reactors, using a newly developed cross section set. Critical mass, breeding ratio, and reactivity coefficients are

presented as a function of reactor size and composition, which in turn are related to reactor power. The effect of various structural materials on performance is examined, as are the differences between "new" and "equilibrium" reactors, and the influence of various blanket design modifications. The effect on performance prediction of various degrees of refinement in the treatment of resonance elastic scattering is discussed. Results obtained with the new cross section set are compared with those of previous sets. Fast reactor performance with the thorium-U-233 fuel system and with hybrid fuel systems is also treated.

The second part of the paper deals with the relation between reactivity coefficients and reactor safety. Efforts to set criteria for Doppler coefficients and sodium void effects are reviewed. Estimates of potential sodium loss rates are made and translated into reactivity insertion rates as a function of reactor design. The relation between Doppler coefficient, sodium void effects, fuel element type, power density and core damage is discussed for some typical accidents.

The third portion of the paper surveys the nuclear designs reported in the four independent 1000 Mwe studies for fast power reactors submitted by various American industrial groups to the United States Atomic Energy Commission in January, 1964. The separate design approaches have led to pancake-shaped reactors, to a large annular core, and to a cluster of more highly enriched, cylindrical cores of modest diameter. The salient nuclear features of these widely differing design approaches are reviewed herein.